

Article

Does Trade Related Sectoral Infrastructure Make Chinese Exports More Sophisticated and Diversified?

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Abstract: Whether better infrastructure influences Chinese export sophistication (ES) and diversification (ED) is an important question, which surprisingly remains unaddressed. The current study contributes to the ES and ED literature by capturing the symmetric and asymmetric effect of infrastructure on ES and ED. We employ a robust dynamically simulated autoregressive distributed lag (DYS-ARDL) dynamic method, which is an extended version of NARDL and ARDL. The major aim of this new DYS-ARDL dynamic approach was to abolish the issue in orthodox ARDL model approach while examining the long-run and short-run. The new dynamic DYS-ARDL model is accomplished in estimating, stimulating, and robotically plotting predictions of counterfactual alterations in one explanatory variable and its impact on the dependent variable while holding the remaining regressors constant. Furthermore, this new method of DYS-ARDL model can estimate, stimulate, and plot to forecast graphs of positive and negative variations in the variables robotically as well as their short and long-run associations. Interestingly, the results of this study witness the presence of long-run relationship between infrastructure and ES and ED in China. The present study shows that better infrastructure will be more beneficial for Chinese ED and ES.

Keywords: infrastructure; export sophistication and diversification; simulated ARDL; China



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1. Introduction

Export sophistication (ES) and export diversification (ED) are important elements in the process of economic development; therefore, countries in the world give due importance to diversification and sophistication of their export [1–3]. They come up with different strategies including enhanced technical knowhow and human capital, optimal utilization of available resources, and expending economies of scale in order to promote ES and ED. One of the best strategies in this regard is to make sound trade related infrastructure, which includes physical connectivity, efficient financial systems, telecommunication, and good quality of energy infrastructure [2,4–8]. If a region is facing the problem of poor trade related infrastructure, it will cause other strategies to be less effective in promoting ES and ED. For example, countries like China, Singapore, Thailand, and Vietnam registered strong growth in international trade, especially exports (Export ratio in Viet Nam further increased by 42% followed by Thailand (49%), India (55%), and Indonesia (63%)) due to better infrastructure [2,9].

Past studies like [2,9,10] linked outward foreign direct investment to ES and ED in China. Refs. [11–15] pointed out that the rise in Chinese ES is due to sophisticated input used in the production process. Xu and Lu [16] and Fang, et al. [17] confirmed the positive impact of FDI on ES in China, Hausmann, et al. [18] and Spatafora, et al. [19] and Rehman, Khan, Khan, Pervaiz and Liaqat [2] show that ES and ED have positive effect on economic growth. Fan, et al. [20] analysed the relationship between cultural diversity and ES in China. Wang and Wei [21] analysed the sophistication level of livestock commodities in African economies by estimating technology intensity and economic complexity of each good by employing the trade data from 1995–2012. Amiti and Smarzynska Javorcik [22] explores the association between ED, trade, and trade liberalization in Sub Saharan African (SSA) economies. According to our best of knowledge we are the first to explore the effect of infrastructure on ES as well as ED in the context of China.

Theoretically, infrastructure improves ES and ED by these channels: transport infrastructure can help a country to connect its remote area domestically and connect to business areas worldwide at low cost which directly improves the export competitiveness and diversifies the export. Refs. [3,23,24] argues that a 10% decrease in transport costs increases trade by 6% while a 10% increase in overall investment in infrastructure contributes 5% to exports in developing countries. On the other hand, lack of infrastructure increases the cost of production, reduces portability, and causes unnecessary delay in economic activities [25,26]. Good quality of energy infrastructure promotes capital-intensified industrialization and thus reduces production cost which ultimately increases ES. Marketing is one of the most important tools of promoting products to capture the market which can be promoted through telecommunication infrastructure. Better financial infrastructure helps to solve financial and liquidity barriers in the way of ES and ED [10,27].

Despite the fact that infrastructure effects the cost of production and level of trade [2], many international trade theories overlooked the role of infrastructure in trade. Traditional international trade theories assumed zero transportation and energy cost which hardly justifies the ground realities at a time when infrastructure services play a dominant role in the regional as well as international trade [28,29].

Previous literature that linked infrastructure to trade, for example [8,30–32], has some limitations. The main limitations in these studies regard the measurement of infrastructure. For example, the number of mobile and landline users was taken as a proxy for telecommunication infrastructure, total area in kilometers of paved and unpaved road for transport infrastructure, and percentage of population having access to electricity for energy infrastructure. Furthermore, some of the recent studies used the railroad networks in India and concluded that economy's trade-off and welfare can be significantly enhanced through connectivity of India with the rest of the world.

Financial infrastructure having a vital role in promotion of trade [11,25,33] is missing in these studies. Such limitations in measurement of the variable blur the picture of the true relationship of infrastructure ES and ED. Such problems were, somehow, tackled in the studies of [27,34] who made index of infrastructure by principal components analysis (PCA), but it unduly restricts the set of countries and the data series that can be incorporated in the analysis and the constructed indices are no longer comparable over time [23]. Infrastructure was somehow thoroughly captured in literature [9,24] as they incorporated comprehensive geographical information on the road, rail, and water infrastructure of the United-States (US) to conclude that these factors account for at least 20% of the spatial welfare distribution across the US.

Keeping such limitations in view, this study employs a new global infrastructure index devised by [35]. Using Unobserved Component Analysis (UCM), the index is constructed based on a yearly dataset of thirty indicators of the quality and quantity of the transport, energy, communication, and financial sectors to better understand the role of infrastructure in promoting ES as well as ED.

We contribute to the existing literature in several ways. First, to the best of our knowledge, this study is the first attempt to examine the effect of sectorial infrastructure on

ES and ED in China. Second, we use a comprehensive index of infrastructure to overcome the aggregation bias. The infrastructure index contains four sub-domains: transport, telecommunication, energy, and financial infrastructure. The index includes 30 indicators by applying Unobserved Component Analysis (UCM). Third, we use a Simulated Dynamic ARDL model to observe the possible effect of trade related sectorial infrastructure on ES and ED in China. The main objective of this new simulated ARDL dynamic approach is to abolish the issues in the orthodox ARDL model approach while examining the long-run and short-run. The new dynamic simulated ARDL model is accomplished at estimating, stimulating, and robotically plotting predictions of counterfactual alterations in one explanatory variable and their impact on the dependent variable while holding the remaining regressors constant. Furthermore, this new method of simulated ARDL model can estimate, stimulate, and plot to forecast graphs of positive and negative variations in the variables robotically as well as their short- and long-run associations [36].

The current research paper is prepared as follows: Section 2 shows a related review of literature. The theory of infrastructure and ES and ED association are explained in Section 3. Data sources and the construction of indices (i.e., ES and ED) are discussed in Section 4. Econometric methodology is explained in Section 5. The results and discussion are shown in Section 6. Finally, the conclusion and policy implication are discussed in Section 7.

2. Sophistication and Diversification of Export in China: A Literature Review

The trade liberalization process was initiated in the 1990s in China and as a result extraordinary output and growth was achieved in the trade, due to which China joined the WTO in the year 2001 [37,38]. The study of Ianchovichina and Martin [37] confirms that major trade partners have gained by this trade agreement but some of the competing rival countries have suffered some losses. China's export growth from 1992 to 2005 was five-fold. The export structure of China has changed from primary sector i.e., agriculture, to secondary sector i.e., manufacturing of electronics and machinery. This export growth is evidence of specialization, which is derived from an intensive margin instead of an extensive margin [22,39]. Xu and Lu [16] argued that Chinese exports have increased remarkably in the previous three decades. Chinese ES are beyond the expectations of its stage of development [40,41]. Gözgör and Can [42] suggested that China's export success is due to government policies compared to a fair market. These government policies have resulted in China creating a significantly sophisticated basket of exports as compared to other countries of the same income level. Studies like Mania and Rieber [43] and Osakwe, et al. [44] emphasize the sophistication of the trade process for Chinese exports. However, some studies suggest that in the case of excluded process, the sophistication is not in depth, rather there is process of change due to which economic growth occurred. Jarreau and Poncet [45] investigated the ES and its impact on the economy in various regions of China from 1997 to 2009 and found significant differences in ES at the provincial and regional levels. It was found that regions specializing in sophisticated goods have faster growth, but the gain is limited to domestic firms due to their amazing export activities and no achievement is gained by the trade process or foreign firms. The cross-city variation in human capital is likened to differences in ES structure and the increase in sophistication is due to government policies regarding high technology and developing economic zones for foreign investment conducive to sophistication of products in China [21]. China ES is the result of foreign investors from the developed countries [16]. Assche and Gangnes [12] claim Chinese high-quality export sophistication is due to high-quality sophistication in input in the trade process. Kireyev [46] studies the production quality aspect by considering its local export value and by adding qualitative parameter of the index of ES which was developed by Hausmann, Hwang and Rodrik [18] and Rodrik [40] for measurement of China's ES. Their study indicates that there is no such sophistication increase which leads to Chinese exports overcoming the advanced countries.

ED refers to producing and trading of various commodities from different economic sectors [4]. This shows that GDP growth rate and the export growth rate are both increased by diversified export baskets [47]. Channels by which ED has a positive effect on growth consist of: (1) the Prebisch–Singer hypothesis, which is related to promoting terms of trade by enhancing production and diversifying trade [48], (2) the ‘portfolio effect’ through which various sector export variety can increase export earning stability [49]; and (3) increase aggregate production level by knowledge [50]. Thus, by diversification, economic instability risk and uncertainty in foreign exchange can be protected. Many studies focus on export structure for analysing the industrial structure in developing countries. Thus, a good proxy for industrial structure will be the export [18,51]. For understanding the export structure, the most commonly used methodology is that of Hausmann, Hwang, and Rodrik [18], which used PRODY as a weighted average of the income per capita of the exporters of that product and EXPY as a weighted average of the income level of the country’s export basket.

ED structure of a country is denoted by its capital and technology endowment in the production process of exports. To this extent, per capita GDP of a country measures its export capability, which is one of the indicators of its ED. Kito, et al. [52] adopted the same methodology for the computation of the domestic and technology content of the exports of China and concluded with contradictory results, as the Zheng and Wang [53] study shows that during 1997 to 2002, there is not only a significant increase in the contents of whole technology in the exports of China but in the same time period there is a significant decrease in the content of domestic technology, although content of domestic technology from the province of Guangdong has faced a U shaped curve trajectory, meaning an initial decrease and then an increase in 1992–2002. Li and Lu [54] stated that China whole technology export contents significantly increased in the previous three decades, with a temporary decrease in domestic content of technology during the period from 1992 to 2002, and claimed that China must catch-up regarding technology.

Many researchers have raised a question regarding the claim of Hausmann, Hwang and Rodrik [18], Rodrik [40], and Schott [41] that ES of China may be overvalued. Aditya and Acharyya [55] considered that measurement of ES of China may be an illusion of statistics raised by the process of trade. Koopman, et al. [56] criticized the calculation of Rodrik [40] and Schott [41] as these have not considered the technological improvement by the exports of a country, thus the observing upgradation of China’s exports may not show the real technology adoption on the local level. They concluded that the content of foreign technology is greater in labeled sectors as compared to sophisticated electronic equipment, telecommunication, and computer devices. Guoming [57] pointed out that a country’s exports is not reflected by sophistication of ES index because the ES index does not tell in detail about the actual value addition. Their study suggests that the ES level of China seems to be more biased as compared to other countries. By applying the index of sophisticated data of electronic products, it was found that China’s electronic production is not remarkably sophisticated. Balamoune-Lutz [58] suggest that the index of ES is not applicable to the quality of the exported product, because their prices are very low and prices are the signals of quality of the products; thus, ES index will overestimate the sophistication level of Chinese products. A similar argument was given by Jarreau and Poncet [45] who noted that the majority of high technology exported products of china are of imported input and are labor-intensive. They argued that the sophistication index of export does not show a higher level of sophistication in the process of manufacturing Chinese products.

Besides these studies about ES of China, along with various measurements from different indices, there is one other category of researchers who have explored the impacts of economic growth on the ES of China. Hu, et al. [59] posited that the ES of developing countries (including China) are due to their deterioration of terms of trade, i.e., that the “new term of trade pessimism” exists. Lectard and Rougier [1] and Shahzad, Ferraz, Doğan, and Aparecida do Nascimento Rebelatto [13] noticed that the enhancement of skill or

technology of exports of China is associated with deterioration in its term of trade. It proved that an increase in ES does not have a significant impact on the economic growth of China. Mania and Rieber [43] found that in developing economies ES plays a vital role in the achievement of economic growth & development and the same happens in the case of China. Jarreau and Poncet [45] confirmed the positive impact of ES on economic growth of China as the regions with specialization in sophisticated goods have higher economic growth.

Previous literature like [4,9,38] intensively analyzed the determinants of ES and ED, but completely ignored the important variables of trade-related sectorial infrastructure in China. The objectives of this research study were to fill in the gap and empirically examine the effect of trade-related sectorial infrastructure on ES and ED. This is an original study which has applied a new DYS-ARDL model in order to find clearer and more in-depth empirical results. The simulated ARDL–dynamic model can estimate, stimulate, and plot to forecast negative and positive changes in graphs, happening in the variables robotically as well as their long- and short-run associations. The simulated ARDL–dynamic model can estimate, stimulate, and plot to forecast negative and positive changes in graphs, happening in the variables robotically as well as their long- and short-run associations [36,60–62]. These are all the benefits of the novel simulated ARDL–dynamic over the initial version of ARDL. The classical version of ARDL can only evaluate the short- and long-run relationships of the selected variables alone.

3. Theoretical Background

The classical international trade theories have discussed how a linkage of economies affects the flow of capital and how it influences the production process of the economies. Vernon [63] proposed the product life cycle theory, which states that invention and innovation [64] require high skill labor and higher cost and the comparative advantage sustained with the innovative country in the initial stages and then shifts to other countries, as production of the product becomes common, with low factor prices. Such transfer of the production process from the innovative country to the host country has aggregate economic consequences. For example, it has influences on the export of both the innovative and host countries, relative factor price differences in both countries, and comparative advantage which are the basis for trade between the trading countries. This mechanism depends on transportation cost, information regarding the market, and ease of transfer of ownership. For example, Xing [65] proposed that digital, financial, and physical connectivity among economies increases exports of both the host country and the partner country. Firstly, the rehabilitation of existing transport infrastructure and the development of new infrastructure will facilitate domestic trade and increase regional and international trade, particularly through reduced costs of doing business, enhancing competitiveness, sophistication, and diversification of exports in domestic, regional, and global markets (see Figures 1 and 2). This will also, in turn, act as a catalyst to economic transformation, sophistication, and diversification through industrialization and value-added processing [26,33,66–68].

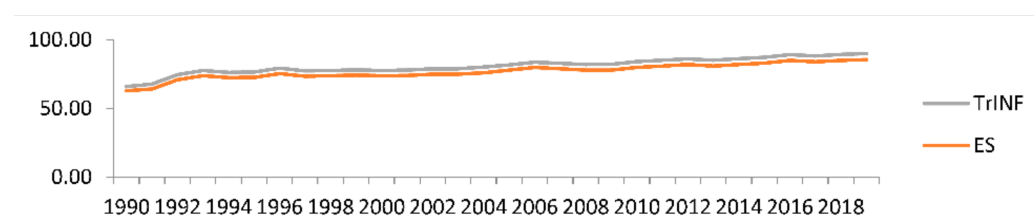


Figure 1. Transport Infrastructure and Export Sophistication in China. Source: Authors' own estimations.

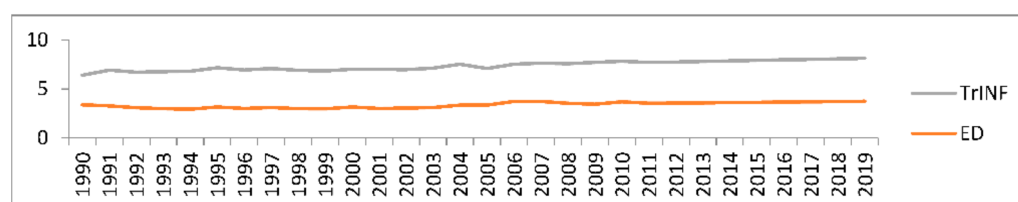


Figure 2. Transport Infrastructure and Export Sophistication in China. Source: Authors' own estimations.

As liberalization continues to reduce artificial barriers, the effective rate of protection provided by transport costs is now, in many cases, higher than the one provided by tariffs. It is striking to realize that for most developing countries, transport costs exceed average tariffs by more than twenty times. Consequently, any additional effort to integrate African countries into the global trading system by improving the competitiveness of their exports should consider and analyze the effect of transport costs and their determinants.

Second, communication and information technology play a significant role in ES and ED, especially in the modern era where efficiency and rapidity of reaction are central in accessing markets, responding to customers, and channeling goods & services across borders [25,33,68]. The boom of e-commerce has made it almost inevitable for business operators to embrace technological development offered by ICT—contacts with potential customers, advertisement, and communication of sales documents and so on are the areas requiring ICTs. Effective telecommunications provide a low-cost channel for searching, gathering, and exchanging information which, in turn, is a key input in all economic activities [10,21]. The discussion shows that the impact of telecommunication infrastructure on ES and ED is positive (Figures 3 and 4).

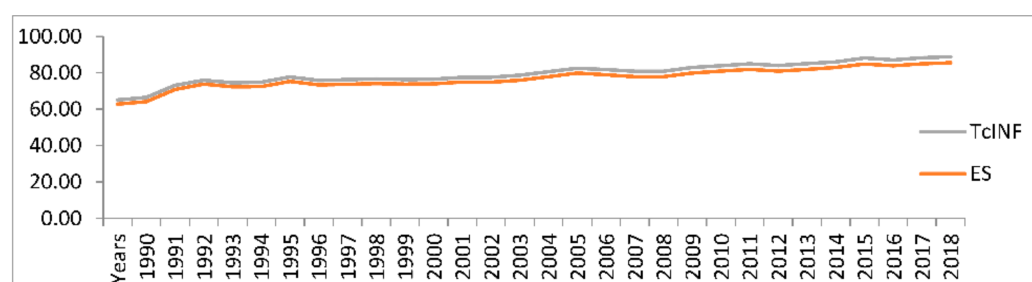


Figure 3. Telecommunication Infrastructure and Export Sophistication in China. Source: Authors' own estimations.

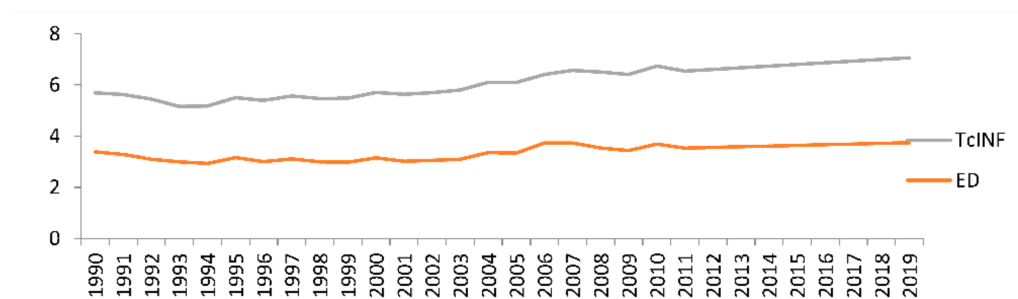


Figure 4. Telecommunication Infrastructure and Export Diversification. Source: Authors' own estimations.

Third, financial infrastructure has a key role in the efficient allocation of resources and time saving in transporting goods which help in facilitating macroeconomic stability. Financial services also play a critical role in the process of transferring commodity ownership across borders to cover the hazard of international trading flows. The quantity and quality

of those services are key components of the transaction cost of trading, which is therefore a part of international trade transactions (Figures 5 and 6) [2,9,69].

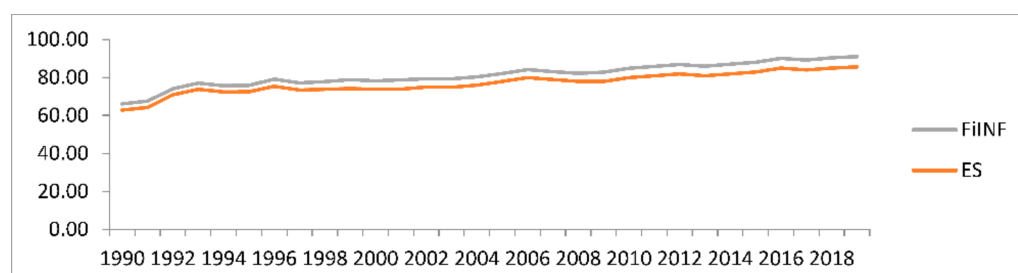


Figure 5. Export Sophistication and Financial Infrastructure. Source: Authors' own estimations.

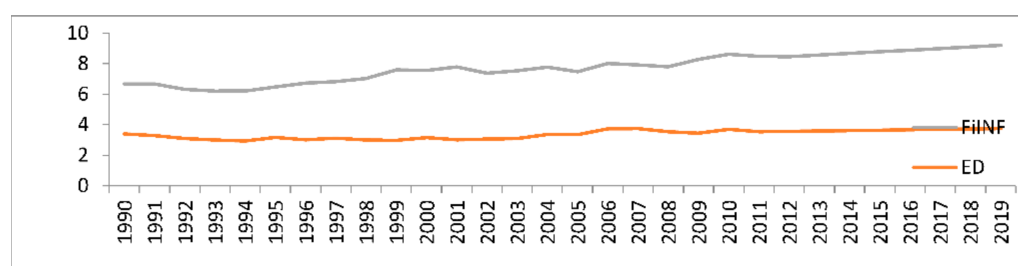


Figure 6. Export Diversification and Financial Infrastructure. Source: Authors' own estimations.

Last but not the least, efficient energy infrastructure (Figures 7 and 8) provides vast opportunities to enhance productivity and gain comparative advantage by gaining energy advantage (for example, reducing energy usage from 30 BTUs to 20 BTUs in the production of one ton of steel) and non-energy advantage (for example, enhancing productivity of labor and thus saving labor input and reducing wastes in the production process) which leads to comparative advantage. Productivity means producing more units of output with a given number of resources like labor, capital, and energy. Larger productivity, specifically in manufacturing goods, is expected when the production process is made capital intensive. Industries are run by machines and it is energy that drives machines, which in turn enhances labor productivity and reduces average cost. Depending upon the degree of substitution between labor and capital in a production process, energy efficiency alters the capital-labor ratio, a change in the capital intensity, which affects productivity. For example, according to the EIB Investment Report (2017–2018), average productivity of labor on the firm level in New Zealand was 73% of Australian labor's average productivity and such a gap in productivity is attributed to the fact that the level of capital per worker in New Zealand is significantly lower than in Australia. Similarly, Rehman, Khan, Khan, Pervaiz, and Liaqat [2] and Rehman and Khan [70] estimate that around quarter of the gap in capital intensity between New Zealand and Australia is due to the fact that the latter country is very efficient in the energy sector. At the aggregate economic level, on average, APL in New Zealand is 69% of the UK level and only 61% of the US level and the level of capital intensity in the UK and US is significantly higher than New Zealand.

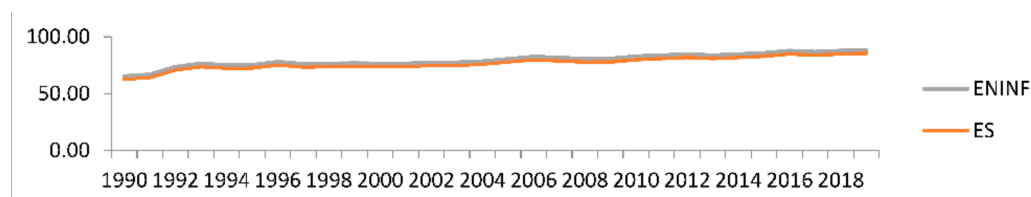


Figure 7. Export Sophistication and Energy Infrastructure. Source: Authors' own estimations.

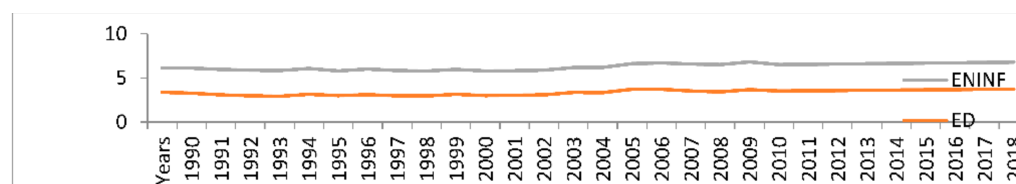


Figure 8. Export Diversification and Energy Infrastructure. Source: Authors' own estimations.

4. Data Collection and Construction of Export Sophistication and Diversification

For empirical findings of the impact of Infrastructure on ES and ED, this study relays the global infrastructure index, constructed by [35]. This developed index comprises 30 variables in order to cover the significant dimensions. An additional four (04) sub-indices of infrastructure are included, i.e., communication (IFC), transport (IFT), financial (IFF), and energy (IFE) to better understand the impact of infrastructure in augmenting ES and ED in China. UCM is employed to determine the weight given to each component in the developing of the index. Detail about the devising of this global infrastructure is established in [35]. We devised an index for ES and ED. The comprehensive detail about ES and ED indices is found in Sections 4.1 and 4.2, respectively. For the other control variables this study used different sources. We used gross fixed capital formation and merchandise export as a proxy for domestic investment (DI) and trade openness (PO) and collected the data from the world development bank (WDI) [10]. The data on outward foreign direct investment (OFDI) was extracted from UNCTAD. The institutional quality index (IQ) is one of the explanatory variables in this study. The data for the IQ index was extracted from the International Country Risk Guide (ICRG). The ICRG database covers six sub-indices of institution quality: investment profile, corruption, law and order situation, democratic accountability, government stability, and bureaucratic quality. Details on the IQ index are found in the recent study of [9].

The global infrastructure index contains negative values which we change to positive values by adding 3 consistently before applying natural log (LN). It is quite imperative to standardize the measurement of the selected variables, as it will remove the homogeneity problem. The LN is a consistent technique of the many methods. The current research study reserved the initiative to standardize the measurement to improve and discover a meaningful interpretation as well.

4.1. Construction of Export Sophistication

The data is the average of a country's income related to the export bundle of that country, and this indicates the quality and nature of the export of the country. It is anticipated that quality product export provides more advantages to export bundles and provides greater income in the global market. In order to construct an index of export sophistication, the Hausmann, Hwang, and Rodrik [18] method is followed in the current study, where first PRODY variables are devised and then the index of ES is estimated.

$$PRODY_k = \sum_i \frac{(x_{ki}/X_i)}{\sum_i (x_{jk}/X_i)} Y_i k \quad (1)$$

where X_{ki}/X_i is the value share of the product k out of the total export of a country i , while Y_i is the per capita GDP of country i . $PRODY_k$ (in Equation (1)) reflects the weighted average measure of GDP per capita and revealed the comparative advantage of a country i exporting product k . Using PRODY, we calculate the following index.

$$ES = \sum_k \left[\left(\frac{X_i^k}{X_i} \right) PRODY^k \right] \quad (2)$$

ES (in Equation (2)) is an average of the PRODY of country i , weighted by the share of product k in country i 's total exports.

4.2. Export Diversification

A country's export structure change can be obtained either by a change in an existing commodities basket or enhanced through technological development and innovations. According to Xu and Lu [16], export diversification means increasing the range of export products of a country. By applying the deification and methodology of Li and Lu [54] the whole intensive as well as extensive indices are calculated. First of all, dummy variables are created in order to define every product as non-traded, new or traditional. Traditional products are those commodities which were exported at the start of the sample, and commodities having zero export in the whole sample are known as non-traded products. So, in our sample for every country and for every product the dummy has constant value for all years. For every product group, year, and country, a new product must have not been traded at least in the past two years and then exported in the coming two years. In this way the new product dummy values may be changed over time. The whole Theil index is used to add up the extensive and intensive components. The Theil index for every country and year pair can be calculated by the following equation.

$$T_B = \sum_k \left(\frac{N_k}{N} \right) \left(\frac{\mu_k}{\mu} \right) \ln \left(\frac{\mu_k}{\mu} \right) \quad (3)$$

Whereas k signifies all groups (i.e., non-traded, traditional and new), N_k is the full number of goods exported in each group, and μ_k/μ is the relative mean of exports in each group. The intensive Theil index for each country per year pair is:

$$T_W = \sum_k \left(\frac{N_k}{N} \right) \left(\frac{\mu_k}{\mu} \right) \left\{ \left(1/N_k \right) \sum_{i \in I_k} \left(\frac{X_i}{\mu_k} \right) \ln \left(\frac{X_i}{\mu_k} \right) \right\} \quad (4)$$

Whereas x symbolizes the value of export.

5. Econometric Methodology

Jordan and Philips [36] introduced an advance version of ARDL model naming: the Dynamic Autoregressive Distributed Lag Simulation model. The objective of this model was to overcome the problems of the simple ARDL model in estimating short-run and long-run model specification. This new model is capable of estimating, simulating, and robotically forecasting counterfactual alteration in one explanatory variable and its impact on explained variables while holding other control variables constant [36,60–62,71]. This model stimulates, estimates, and plots graphs of predicted positive and negative variation in the variables automatically and also shows their short-run and long-run relationship. Pesaran, et al. [72] ARDL model is limited to estimation of short-run and long-run variable relationships. All variables in this study are integrated at level or first difference, i.e., $I(0)$ or $I(1)$ and stationary, which indicate the applicability of this new dynamic DYS-ARDL model. The counterfactual alterations in the explanatory variables and their impact of explained variables are graphically shown in the study. Like earlier studies conducted by [36,60,61,71] the results of this new dynamic DYS-ARDL error correction equation are as below:

$$\begin{aligned}
\Delta \ln ES = & \alpha_{0ES} + \sum_{i=1}^p \psi_{iES} \Delta \ln ES + \sum_{i=1}^p \phi_{iES} \Delta \ln GNF_{t-i} + \sum_{i=1}^p \delta_{iES} \Delta \ln TNF_{t-i} \\
& + \sum_{i=1}^p \omega_{iES} \Delta \ln CNF_{t-i} + \sum_{i=1}^p \varpi_{iES} \Delta \ln FNF_{t-i} \\
& + \sum_{i=1}^p \theta_{ES} \Delta \ln ENF + \sum_{i=1}^p \pi_{ES} \Delta \ln INQ + \sum_{i=1}^p \eta_{ES} \Delta \ln OFDI + \sum_{i=1}^p \omega_{ES} \Delta \ln DI \\
& + \sum_{i=1}^p \theta_{ES} \Delta \ln TO + \\
& \lambda_{1ES} \ln ES_{t-1} + \lambda_{2ES} \ln GNF_{t-1} + \lambda_{3ES} \ln CNF_{t-1} + \lambda_{4ES} \ln ENF_{t-1} \\
& + \lambda_{5ES} \ln FNF_{t-1} + \lambda_{6ES} \ln INQ_{t-1} \\
& + \lambda_{7ES} \ln OFDI_{t-1} + \lambda_{8ES} \ln DI_{t-1} + \lambda_{9ES} \ln TO_{t-1} + \mu_{1t} \\
\Delta \ln ED = & \alpha_{0ED} + \sum_{i=1}^p \psi_{iED} \Delta \ln ED + \sum_{i=1}^p \phi_{iED} \Delta \ln GNF_{t-i} \\
& + \sum_{i=1}^p \delta_{iED} \Delta \ln TNF_{t-i} + \sum_{i=1}^p \omega_{iED} \Delta \ln CNF_{t-i} \\
& + \sum_{i=1}^p \varpi_{iED} \Delta \ln FNF_{t-i} \\
& + \sum_{i=1}^p \theta_{ED} \Delta \ln ENF + \sum_{i=1}^p \pi_{ED} \Delta \ln INQ + \sum_{i=1}^p \eta_{ED} \Delta \ln OFDI + \sum_{i=1}^p \omega_{ED} \Delta \ln DI \\
& + \sum_{i=1}^p \theta_{ED} \Delta \ln TO + \\
& \lambda_{1ED} \ln ED_{t-1} + \lambda_{2ED} \ln GNF_{t-1} + \lambda_{3ED} \ln CNF_{t-1} + \lambda_{4ED} \ln ENF_{t-1} \\
& + \lambda_{5ED} \ln FNF_{t-1} + \lambda_{6ED} \ln INQ_{t-1} \\
& + \lambda_{7ED} \ln OFDI_{t-1} + \lambda_{8ED} \ln DI_{t-1} + \lambda_{9ED} \ln TO_{t-1} + \mu_{1t}
\end{aligned} \tag{5}$$

$$\begin{aligned}
& + \sum_{i=1}^p \theta_{ED} \Delta \ln TO + \\
& \lambda_{1ED} \ln ED_{t-1} + \lambda_{2ED} \ln GNF_{t-1} + \lambda_{3ED} \ln CNF_{t-1} + \lambda_{4ED} \ln ENF_{t-1} \\
& + \lambda_{5ED} \ln FNF_{t-1} + \lambda_{6ED} \ln INQ_{t-1} \\
& + \lambda_{7ED} \ln OFDI_{t-1} + \lambda_{8ED} \ln DI_{t-1} + \lambda_{9ED} \ln TO_{t-1} + \mu_{1t}
\end{aligned} \tag{6}$$

Whereas Δ shows short run, \ln indicates natural log, μ_1 and μ_2 express error term, p displays lags of the variable, and λ shows long run.

6. Results and Discussion

Prior to checking the impact of infrastructure on ES and ED, it is important to observe first whether the selected variables of the study are stationary at order of first difference $I(1)$ or level $I(0)$; if not, then the empirical results outcomes will be void. Table 1 shows two different unit root tests results such as augmented dickey fuller (ADF) and Phillip-Perron (PP), which were applied to examine the integration order of the selected variables. The results of Table 1 revealed that all the chosen variables of the current study are integrated and stationary at the order of $I(1)$ and $I(0)$ that approve the method of the new dynamic DYS-ARDL model, which was developed by [36]. The DYS-ARDL model allowed us to select diverse lags for regressors and regressend. Table 2 shows the results of descriptive statistics.

Table 1. Unit Root test Results.

Variables	ADF Test		DF-GLS Test	
	I(0)	I(1)	I(0)	I(1)
LNGNF	−1.987	−5.360 ***	−1.542	−5.49 ***
LNTNF	−5.577 ***	−6.381 ***	−5.801 ***	−6.638 ***
LNCNF	−2.075	−5.377 ***	−1.969	−5.488 ***
LNENF	−4.724 ***	−6.102 ***	−4.868 ***	−6.387 ***
LNFNF	−1.838	−4.927 ***	−1.392	−5.128 ***
LNINQ	−1.279	−4.397 ***	−1.398	−4.591 ***
LNES	−2.852	−3.362 **	−2.977 *	−3.542 ***
LNOFDI	−5.686 ***	−5.344 ***	−5.892 ***	−5.351 ***
LNED	−1.483	−3.753 **	−1.581	−3.935 ***
LNTD	−2.554	−3.224 **	−2.702	−3.368 ***
LNDI	−2.402	−6.345 ***	−2.538	−6.157 ***

Source: Authors own calculations. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table 2. Descriptive Statistics.

Variable	Obs	Mean	Std.Dev.	Min	Max
LNED	30	1.208	0.086	1.075	1.32
LNES	30	4.34	0.075	4.14	4.449
LNGNF	30	1.279	0.133	0.954	1.475
LNINQ	30	3.261	0.089	3.06	3.376
LNTD	30	−10.092	0.22	−10.366	−9.657
LNOFDI	30	9.475	1.891	6.721	12.187
LNDI	30	−0.461	0.135	−0.695	−0.273

Source: Authors own calculations.

Before examining the results of the simulated dynamic ARDL bound test, this study used an ARDL bound test to assess the long-run relationship between the variables of the study. The acceptance or rejection of the null hypothesis is based upon the F-statistic narrated critical values that are applicable only on a large sample size and are not applicable on small sample sizes.) results. There exist long-run relationships between variables of the study if the F-statistic values are greater than lower bounds values [72]. If the F-statistic values are between the lower and upper bounds values, then there will be uncertainty about the decision. The ARDL Model is comparatively more useful than time series models [72–75]. For short time period data, the classical ARDL model is used [76]. The ARDL model can be applied when variables of the study are integrated at level or first order, i.e., I(0) or (1). For statistical analysis of this study, various lags are used for dependent and independent variables. The results of the ARDL bound test show the existence of integration among the variables. We followed the ARDL model for assessment of variables' long-run relationship.

The results in Table 3 display the ARDL bound tests. All the chosen variables utilized in this study are integrated as the value of F statistics is higher than the upper bound value at the 10%, 5%, and 2.5% levels of significance. For long-run relationship, Wald-based bound test is used for empirical estimation in Table 3, and is applied in Equations (5) and (6) in a way that the explanatory variables, namely aggregate infrastructure and its sub-indices i.e., transport, telecommunication, energy and financial infrastructure, IQ, domestic investment, and trade openness, are regularly presented to the integration associations between infrastructure, ES and ED. The significant values of F-values in Table 3 accept the alternative hypothesis and reject the null hypothesis. These empirical results suggest that a plausible long-run association among infrastructure, ES, and ED along with the selected control variables exists. The significant role of IQ, outward foreign direct investment, domestic investment, and trade openness in ED and ES approves the results of [2,4]. The

introduction of IQ, outward foreign direct investment, domestic investment, and trade openness to the equations significantly augmented the models power.

Table 3. ARDL Bound Results.

Export Sophistication			Export Diversification		
Variables	F-Stat	K	Variables	F-Stat	K
ES/GNF	9.13 ***	1	ES/GNF	3.12	1
ES/GNF/FNF	12.76 ***	2	ES/GNF/FNF	5.76 *	2
ES/GNF/FNF/CNF	7.14 ***	3	ES/GNF/FNF/CNF	8.43 ***	3
ES/GNF/FNF/CNF/ENF	5.65 ***	4	ES/GNF/FNF/CNF/ENF	6.54 ***	4
ES/GNF/FNF/CNF/ENF/TNF	6.76 ***	5	ES/GNF/FNF/CNF/ENF/TNF	5.54 ***	5
ES/GNF/FNF/CNF/ENF/TNF/INQ	7.87 ***	6	ES/GNF/FNF/CNF/ENF/TNF/QI	7.18 ***	6
ES/GNF/FNF/CNF/ENF/TNF/QI/TO	5.91 ***	7	ES/GNF/FNF/CNF/ENF/TNF/QI/TO	6.32 ***	7
ES/GNF/FNF/CNF/ENF/TNF/INQ/TO/OFDI	6.37 ***	8	ES/GNF/FNF/CNF/ENF/TNF/INQ/TO/OFDI	7.19 ***	8

Source: Authors calculations. *** $p < 0.01$, * $p < 0.1$

This study performs different econometrics tests (such as ARCH, Breusch-Pagan Godfrey, Breusch-Godfrey LM, Jarque-Bera, and Ramsey RESET), presented in Table 4. These tests were used to check the reliability of the models. The empirical results of the Breusch Godfrey LM test demonstrated that there is an absent serial correlations problem in the model. The outcomes of the ARCH and Breusch-Pagan-Godfrey test reveal that there is no heteroscedasticity problem. Ramsey RESET test results present that the models have a good fit or are appropriate, whereas for the normality of the model, Jarque-Bera test is employed, which displays that the present model residuals are normally distributed.

Table 4. Diagnostic Tests.

Econometric Problem	Test	F-Stat	p-Value	Null Hypothesis Accepted/Rejected	Equation No.
Serial Correlation	Breusch-Godfrey-LM	0.586	0.568	accepted	Equation (5)
Heteroscedasticity	Breusch-Pagan-Godfrey	0.391	0.712	Accepted	
Specification	Ramsey RESET	3.64	0.13	Accepted	
Normality	Jarque-Bera	4.57	0.14	Accepted	
Serial Correlation	Breusch-Godfrey LM	1.14	0.16	Accepted	Equation (6)
Heteroscedasticity	Breusch-Pagan-Godfrey	3.06	0.12	Accepted	
Specification	Ramsey RESET	0.05	0.86	Accepted	
Normality	Jarque-Bera	0.528	0.96	accepted	

Source: Authors Calculations.

Table 5 displays the empirical results of a simulated ARDL-dynamic model. The simulated ARDL-dynamic model can estimate, simulate, and plot to forecast negative and positive changes in the graphs happening in the variables robotically as well as their long- and short-run associations (see Figures 9 and 10). These are all the benefits of the novel simulated ARDL-dynamic over the initial version of ARDL. The classical version of ARDL can only evaluate the short- and long-run relationships of the selected variables alone. The empirical results of a simulated ARDL-dynamic model are shown in Table 5. The empirically evaluated outcomes in Table 5 confirmed that the aggregated (LNGNF), transport (LNTNF), telecommunication (LNCNF), and energy infrastructure (LNENF) effects export sophistication (LNEs) in the short run positively and significantly while only a positive effect is observed in the long run in China. Financial infrastructure affects ES positively but insignificantly. The present empirical results are consistent with the idea that physical, financial, and digital connectivity among countries increases export volume in both economies, i.e., the partner country and the host country. First, the renovation and development in the existing transport infrastructure and development of the new infrastructure will enhance international, regional, and local trade by reducing business operational cost and creating a competitive environment in the international, regional, and local markets. It will play the role of catalyst in ES, ED, and transformation by the process of value addition and industrialization [1,13]. In addition, the role of digital finance

has increased manifold in economic growth [77]; thus, it is imperative to consider its dynamics in ES and ED. Likewise, internationalization of SMEs may also be beneficial in enhancing export patterns [78]. The results of other regressors, i.e., institutional quality, (INQ), outward foreign direct investment (OFDI), domestic investment (DI), and trade openness (TO), are positive on ES. These results are in the line of Wang and Wei [21] and Lemoine and Ünal-Kesenci [31] in the long as well as in the short run in China. The ECTt−1 values in the upper half of Table 5 represent fast adjustment to equilibrium by ES.

Table 5. Impact of infrastructure on export diversification.

	(1)	(2)	(3)	(4)	(5)
	lned	lned	lned	lned	lned
L1_LNED	−0.825 *** (0.194)	−0.777 *** (0.265)	−0.515 ** (0.220)	−0.679 *** (0.173)	−0.555 ** (0.206)
D_LNGNF	−0.303 (0.331)				
L1_LNGNF	1.042 ** (0.442)				
D_LNTNF		0.074 (0.309)			
L1_LNTNF		0.268 (0.391)			
D_LNCNF			0.092 (0.455)		
L1_LNCNF			0.371 (0.511)		
D_LNENF				1.139 ** (0.417)	
L1_LNENF				0.757 (0.476)	
D_LNFNF					0.032 (0.077)
L1_LNFNF					0.033 (0.117)
D_LNINQ	0.053 (0.132)	−0.018 (0.147)	−0.105 (0.137)	−0.130 (0.118)	−0.121 (0.140)
D_LNTO	0.083 (0.078)	0.027 (0.089)	0.079 (0.094)	0.049 (0.075)	0.057 (0.091)
D_LNOFDI	0.003 (0.014)	0.001 (0.017)	−0.004 (0.017)	−0.018 (0.015)	−0.007 (0.016)
D_LNDI	6.194 * (3.161)	6.976 * (3.617)	7.181 * (3.742)	5.277 (3.208)	6.970 * (3.764)
L1_LNINQ	−0.035 (0.129)	−0.120 (0.141)	−0.219 (0.140)	−0.258 * (0.123)	−0.212 (0.143)
L1_LNTO	−0.087 (0.065)	−0.006 (0.058)	−0.002 (0.062)	0.036 (0.052)	0.021 (0.066)
L1_LNOFDI	0.001 (0.015)	0.010 (0.016)	0.000 (0.019)	−0.023 (0.019)	0.004 (0.016)
L1_LNDI	1.616 *** (0.526)	0.579 ** (0.229)	0.788 (0.582)	0.632 *** (0.186)	0.366 (0.306)
_cons	2.227 ** (0.909)	1.714 (1.095)	1.950 (1.182)	1.656 * (0.844)	1.561 (1.018)
Obs.	29	29	29	29	29
R-squared	0.725	0.649	0.619	0.724	0.606
ECT(−1)	−0.49 *	−0.53 **	−0.51 **	−0.56 **	−0.47 *

Standard errors are in parenthesis. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

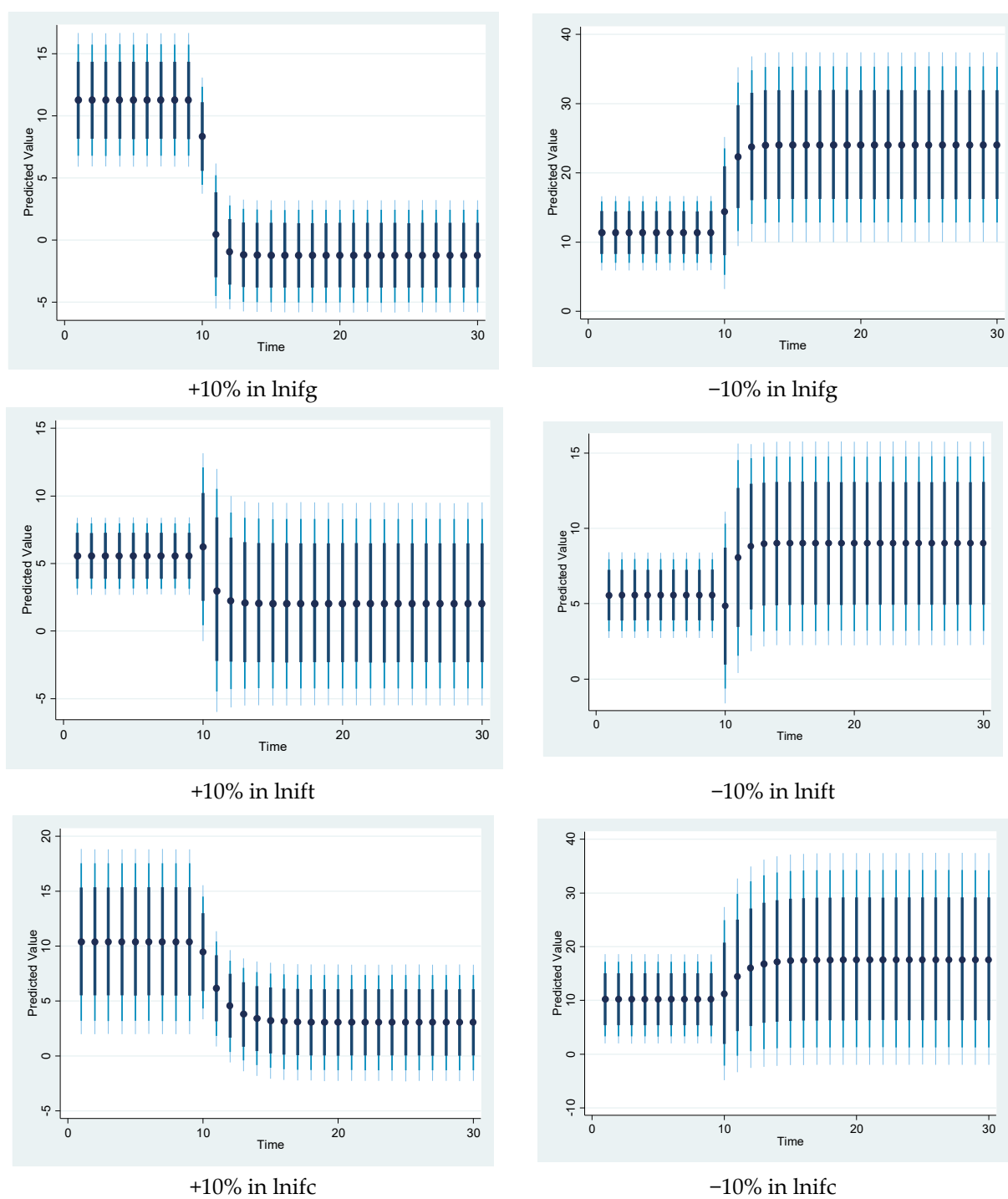


Figure 9. Cont.

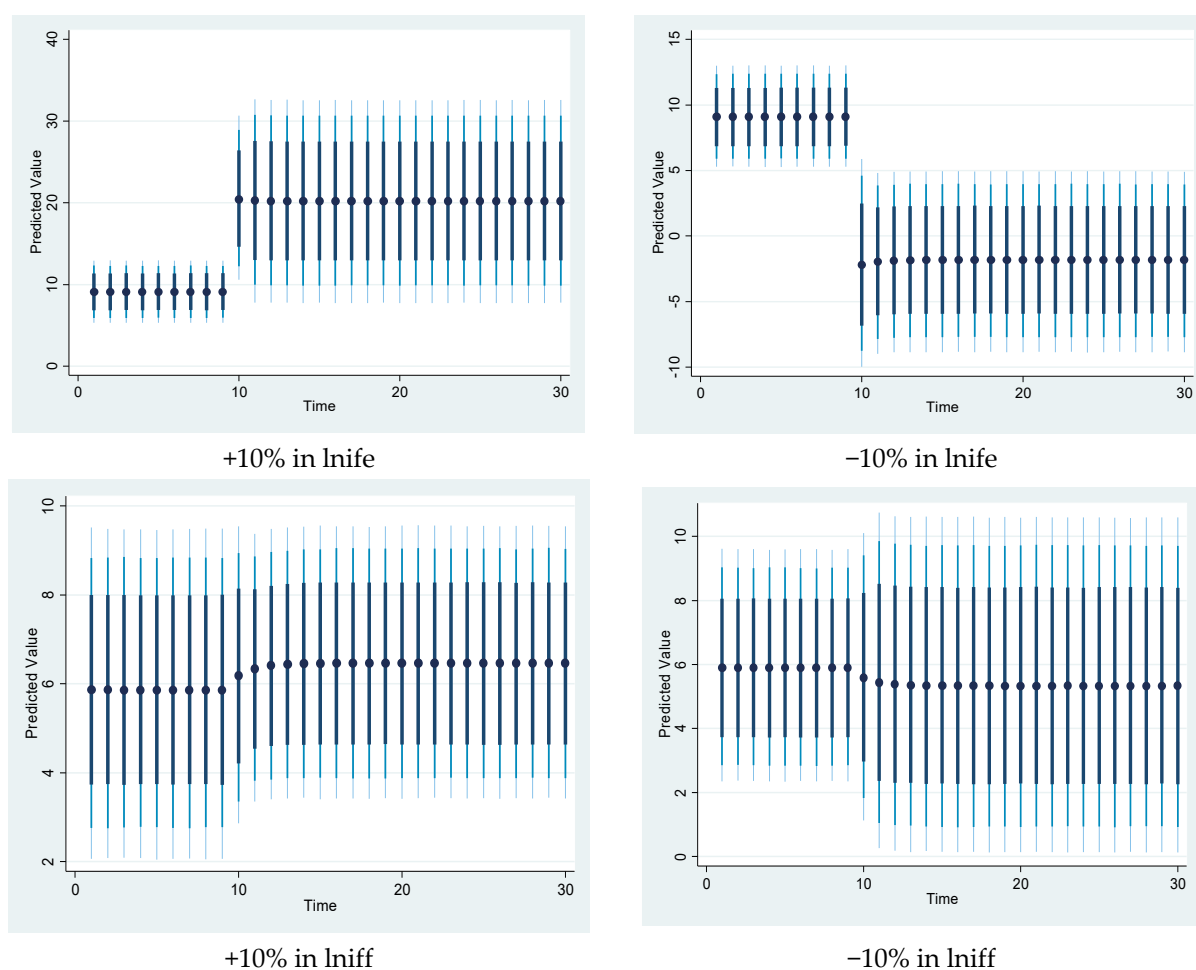


Figure 9. Response of export diversification to 10% +/− shock in lnng, lnift, lnifc, lnife, and lniff respectively.

Table 6 shows the effect of infrastructure on ED in China. The empirically evaluated outcomes confirmed that the aggregated (LNGNF) and energy infrastructure (LNENF) effects ED (LNED) in the long run positively and significantly while transport and telecommunication infrastructure (LNTNF) impact LNED positively but insignificantly in China. The present empirical results are similar to the idea of Zheng and Wang [53] in that connectivity of participating countries leads to ED. The development of existing and new infrastructure will reduce the business operational cost, which will enhance ED. It will boost ED and transformation by value addition and industrialization [2,4]. The results of other regressors, i.e., IQ (INQ), outward foreign direct investment (OFDI), domestic investment (DI), and trade openness (TO), are positive on ED. These results are in the line with [2,4,9] in the long as well as in the short run in China. The ECT_{t-1} values in the upper half of Table 6 represent fast adjustment to equilibrium by export diversification.

The empirical outcomes of Tables 5 and 6 show that 10% rise in aggregated infrastructure has a significant and positive impact on ES and ED in China up to 0.238%, 1.042% in the long-run, and −0.431%, −0.303% in the short-run, respectively. These results are similar to the studies of [2,9]. According to the outcomes a 1% increase in transport infrastructure affects ES and ED positively up to 0.021%, 0.265% in the long run and positively impacts in the short run up to 0.225%, 0.074%, respectively. These results are confirmed by the outcomes of previous studies like [2,9]. Similarly, a 1% rise in telecommunication infrastructure effects ES and ED positively up to 0.628%, 0.371% in long run and in the short run up to 0.654, 0.092% respectively. This result is similar to the studies of [2,9]. A 1% upsurge in energy infrastructure effects ES and ED positively up to 0.332%, 0.057% in the long run and significantly up to 0.714%, 1.039% in short run, respectively. The results

are consistent with the previous studies [2,9]. Additionally, a 1% improvement in financial infrastructure impacts ES and ED positively up to 0.029%, 0.033% in the long run and up to 0.023%, 0.032% in the short run, respectively. These results are supported by the previous studies like [23,35].

Table 6. Impact of infrastructure on export sophistication.

	(1)	(2)	(3)	(4)	(5)
	lnes	lnes	lnes	lnes	lnes
L1_LNES	−0.599 *** (0.189)	−0.500 *** (0.143)	−0.753 ** (0.271)	−0.446 *** (0.128)	−0.448 ** (0.181)
D_LNGNF	−0.413 * (0.215)				
L1_LNGNF	0.238 (0.273)				
D_LNTNF		0.225 * (0.123)			
L1_LNTNF		0.021 (0.130)			
D_LNCNF			0.654 *** (0.225)		
L1_LNCNF			−0.628 (0.366)		
D_LNENF				0.714 *** (0.176)	
L1_LNENF				0.332 (0.207)	
D_LNFNF					0.023 (0.039)
L1_LNFNF					−0.029 (0.062)
D_LNINQ	0.089 (0.073)	0.054 (0.063)	0.132 * (0.064)	0.120 ** (0.053)	0.130 * (0.075)
D_LNTO	−0.033 (0.043)	0.011 (0.036)	−0.014 (0.039)	0.026 (0.033)	0.018 (0.046)
D_LNOFDI	0.009 (0.007)	0.012 * (0.006)	0.011 * (0.007)	0.021 *** (0.006)	0.013 * (0.008)
D_LNDI	0.836 (1.711)	1.062 (1.559)	1.933 (1.584)	2.609 * (1.394)	1.518 (1.935)
L1_LNINQ	0.058 (0.092)	−0.016 (0.067)	0.038 (0.068)	0.059 (0.059)	0.074 (0.083)
L1_LNTO	−0.052 (0.039)	−0.017 (0.025)	−0.053 * (0.027)	−0.038 (0.022)	−0.040 (0.034)
L1_LNOFDI	0.008 (0.007)	0.014 ** (0.006)	0.005 (0.007)	0.029 *** (0.009)	0.014 * (0.008)
L1_LNDI	0.397 (0.376)	0.029 (0.103)	0.936 * (0.486)	−0.045 (0.092)	0.109 (0.192)
_cons	2.294 ** (0.880)	1.896 *** (0.638)	3.609 ** (1.519)	1.390 ** (0.548)	1.242 (0.759)
Obs.	29	29	29	29	29
R-squared	0.750	0.783	0.777	0.829	0.659
ECT(−1)	−0.56 **	−0.59 **	−0.57 **	−0.53 **	−0.57 **

Standard errors are in parenthesis. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

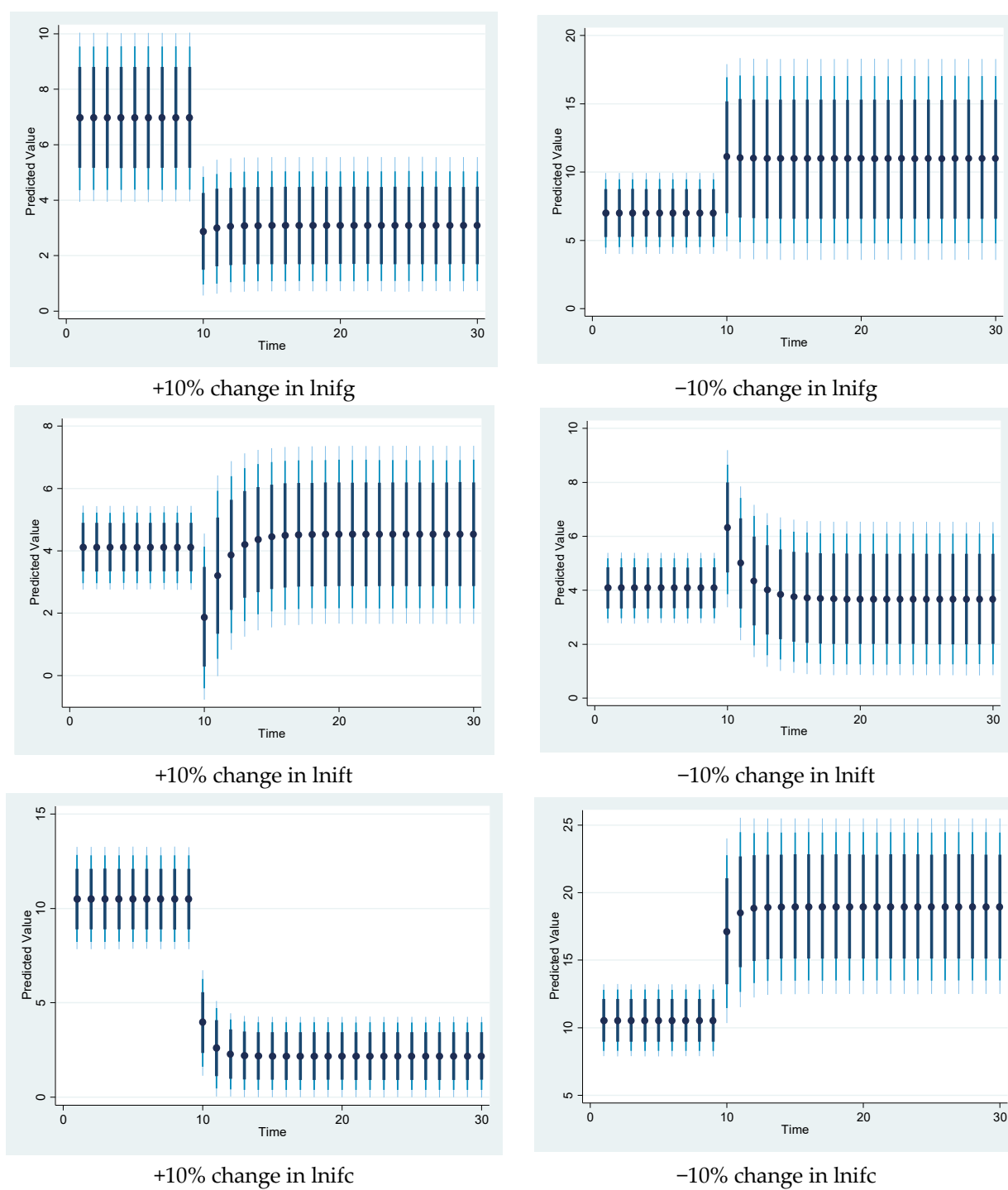


Figure 10. Cont.

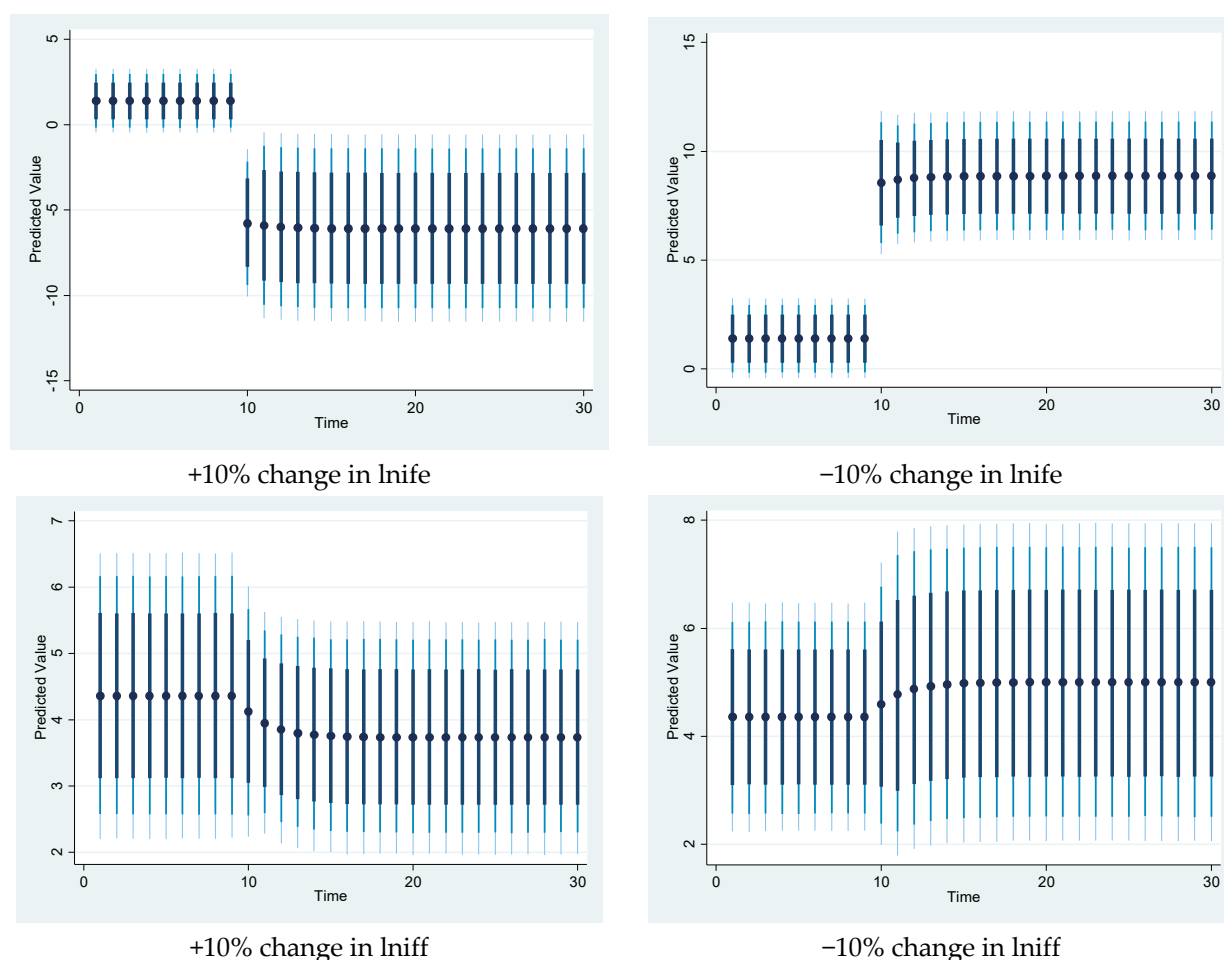


Figure 10. Response of ES to 10% +/– shock in lnng, lnift, lnifc, lnife, and lniff respectively.

7. Conclusions

Lack of infrastructure deteriorates market connectivity; it puts hindrances in reaping trade potential, creates frictions in the market and imposes unnecessary delays, and thus increases the overall cost of production, which adversely affects ES and ED. Also, absence of better infrastructure reduces trade and increases frictions in the connectivity of economic activities across borders. Poor quality of infrastructure adversely affects the comparative edge of an economy while the availability of infrastructure improves its comparative advantage, both on international as well as on domestic fronts. Economies with well-connected infrastructure play a significant role in international trade while countries with deteriorating infrastructure play a less than desirable role in international trade and economic integration.

Previous literature like [2,4,9] explored foreign direct investment, ES, and ED in China. Amiti and Freund [11], Xu and Lu [16], and Fang, Gu, and Li [17] confirmed the positive impact of FDI on the ES in China. Refs. [12,18,50] examined that the effect of ES and ED on economic growth is positive and significant. Fan, Anwar, and Huang [20] analysed the relationship between cultural diversity and ES in China. To the best of our knowledge, prior empirical research studies completely ignored the impact of infrastructure on ES and ED in China. The purpose of the present study is to fill this gap by employing time series data to understand how infrastructure effects ED and ES in China. We used a new simulated ARDL dynamic approach on annual data from 1990–2019 to examine the long as well as short-run association. The empirical results of the present study verified that the significant causal relationship between aggregated infrastructure and disaggregated infrastructure (i.e., transport, telecommunication, energy and financial) and ED as well as ES in China suggests

that infrastructure boosts ES and ED (i.e., Aggregated and disaggregated infrastructure have significant positive impact on ED and ES in short-run and long-run). This is interesting news for policymakers in China who want to catchup on advanced economies and reduce the gap between China and developed economies, particularly in exporting high-tech commodities. These empirical results also deny the claim of Li and Lu [54] that Chinese firms do not donate to ED. Rather, the result shows that Chinese firms today are more skill intensive and confident, and thus encouraging the development of domestic firms could be an effective way to improve ED and ES in China. Besides the main variables (i.e., aggregated and disaggregated infrastructure), the control explanatory variables like INQ, DI, OFDI, and TO also have positive and significant effects on the ED and ES open and reform policy and to further develop the infrastructure system is also important for the advancement of the export structure of China.

The limitation of the current study is that we used a single country i.e., China, for the empirical analysis. For future research it is possible and will be valuable if researchers take different developed and underdeveloped economies which will definitely have a significant contribution for ED, ES, and infrastructure literature.

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References

1. Lectard, P.; Rougier, E. Can Developing Countries Gain from Defying Comparative Advantage? Distance to Comparative Advantage, Export Diversification and Sophistication, and the Dynamics of Specialization. *World Dev.* **2018**, *102*, 90–110. [\[CrossRef\]](#)
2. Rehman, F.U.; Khan, M.A.; Khan, M.A.; Pervaiz, K.; Liaqat, I. The causal, linear and nonlinear nexus between sectoral FDI and infrastructure in Pakistan: Using a new global infrastructure index. *Res. Int. Bus. Financ.* **2019**, *52*, 101129. [\[CrossRef\]](#)
3. Santos-Paulino, A.U. Trade specialization, export productivity and growth in Brazil, China, India, South Africa, and a cross section of countries. *Econ. Chang. Restruct.* **2011**, *44*, 75–97. [\[CrossRef\]](#)
4. Rehman Faheem, U.; Ding, Y.; Noman Abul, A.; Khan Muhammad, A. China's outward foreign direct investment and exports diversification: An asymmetric analysis. *J. Chin. Econ. Foreign Trade Stud.* **2020**, *13*, 45–69. [\[CrossRef\]](#)
5. Islam, M.A.; Khan, M.A.; Popp, J.; Sroka, W.; Oláh, J. Financial Development and Foreign Direct Investment—The Moderating Role of Quality Institutions. *Sustainability* **2020**, *12*, 3556. [\[CrossRef\]](#)
6. Rehman, F.U.; Noman, A.A. Does infrastructure promote exports and foreign direct investment in selected Southeast Asian economies? An application of global infrastructure index. *J. Econ. Stud.* **2020**. [\[CrossRef\]](#)
7. Rehman, F.U.; Noman, A.A.; Ding, Y. Does infrastructure increase exports and reduce trade deficit? Evidence from selected South Asian countries using a new Global Infrastructure Index. *J. Econ. Struct.* **2020**, *9*, 10. [\[CrossRef\]](#)
8. Ismail, N.W.; Mahyideen, J.M. The Impact of infrastructure on trade and economic growth in selected economies in Asia. *SSRN Electron. J.* **2015**. [\[CrossRef\]](#)
9. Rehman, F.U.; Noman, A.A. Trade related sectorial infrastructure and exports of belt and road countries: Does belt and road initiatives make this relation structurally instable? *China Econ. J.* **2020**, 1–25. [\[CrossRef\]](#)
10. Rehman, F.U.; Ding, Y.; Noman, A.A.; Khan, M.A. The Nexus Between Infrastructure and Export: An Empirical Evidence from Pakistan. *Glob. J. Emerg. Mark. Econ.* **2020**, *12*, 141–157. [\[CrossRef\]](#)

11. Amiti, M.; Freund, C. China's export boom. *Financ. Dev.* **2007**, *44*, 38–41.
12. Assche, A.V.; Gangnes, B. Electronics production upgrading: Is China exceptional? *Appl. Econ. Lett.* **2010**, *17*, 477–482. [\[CrossRef\]](#)
13. Shahzad, U.; Ferraz, D.; Doğan, B.; Aparecida do Nascimento Rebelatto, D. Export product diversification and CO₂ emissions: Contextual evidences from developing and developed economies. *J. Clean. Prod.* **2020**, *276*, 124146. [\[CrossRef\]](#)
14. Majeed, A.; Jiang, P.; Ahmad, M.; Khan, M.A.; Olah, J. The Impact of Foreign Direct Investment on Financial Development: New Evidence from Panel Cointegration and Causality Analysis. *J. Compet.* **2021**, *13*, 95–112. [\[CrossRef\]](#)
15. Li, C.; Pervaiz, K.; Khan, M.A.; Rehman, F.U.; Oláh, J. On the Asymmetries of Sovereign Credit Rating Announcements and Financial Market Development in the European Region. *Sustainability* **2019**, *11*, 6636. [\[CrossRef\]](#)
16. Xu, B.; Lu, J. Foreign direct investment, processing trade, and the sophistication of China's exports. *China Econ. Rev.* **2009**, *20*, 425–439. [\[CrossRef\]](#)
17. Fang, Y.; Gu, G.; Li, H. The impact of financial development on the upgrading of China's export technical sophistication. *Int. Econ. Econ. Policy* **2015**, *12*, 257–280. [\[CrossRef\]](#)
18. Hausmann, R.; Hwang, J.; Rodrik, D. What you export matters. *J. Econ. Growth* **2007**, *12*, 1–25. [\[CrossRef\]](#)
19. Spatafora, M.N.; Anand, R.; Mishra, M.S. *Structural Transformation and the Sophistication of Production*; International Monetary Fund: Washington, DC, USA, 2012.
20. Fan, Z.; Anwar, S.; Huang, S. Cultural diversity and export sophistication. *Int. Rev. Econ. Financ.* **2018**, *58*, 508–522. [\[CrossRef\]](#)
21. Wang, Z.; Wei, S.-J. What accounts for the rising sophistication of China's exports? In *China's Growing Role in World Trade*; University of Chicago Press: Chicago, IL, USA, 2010; pp. 63–104.
22. Amiti, M.; Smarzynska Javorcik, B. Trade costs and location of foreign firms in China. *J. Dev. Econ.* **2008**, *85*, 129–149. [\[CrossRef\]](#)
23. Donaubauer, J.; Meyer, B.E.; Nunnenkamp, P. A New Global Index of Infrastructure: Construction, Rankings and Applications. *World Econ.* **2016**, *39*, 236–259. [\[CrossRef\]](#)
24. Duranton, G.; Morrow, P.M.; Turner, M.A. Roads and Trade: Evidence from the US. *Rev. Econ. Stud.* **2014**, *81*, 681–724. [\[CrossRef\]](#)
25. Portugal-Perez, A.; Wilson, J.S. Export Performance and Trade Facilitation Reform: Hard and Soft Infrastructure. *World Dev.* **2012**, *40*, 1295–1307. [\[CrossRef\]](#)
26. Wessel, J. Evaluating the transport-mode-specific trade effects of different transport infrastructure types. *Transp. Policy* **2019**, *78*, 42–57. [\[CrossRef\]](#)
27. Francois, J.; Manchin, M. Institutions, Infrastructure, and Trade. *World Dev.* **2013**, *46*, 165–175. [\[CrossRef\]](#)
28. Garsous, G. *How Productive Is Infrastructure? A Quantitative Survey*; ECARES Working Paper; Universite libre de Bruxelles: Brussels, Belgium, 2012.
29. Horvat, T.; Bendix, H.; Bobek, V.; Skoko, H. Impacts of investments in infrastructure projects on emerging markets' growth: The case of East African countries. *Econ. Res. Ekon. Istraz.* **2020**, 1–27. [\[CrossRef\]](#)
30. Hoffmann, M. Cross-country evidence on the link between the level of infrastructure and capital inflows. *Appl. Econ.* **2003**, *35*, 515–526. [\[CrossRef\]](#)
31. Lemoine, F.; Ünal-Kesenci, D. Assembly Trade and Technology Transfer: The Case of China. *World Dev.* **2004**, *32*, 829–850. [\[CrossRef\]](#)
32. Roller, L.-H.; Waverman, L. Telecommunications infrastructure and economic development: A simultaneous approach. *Am. Econ. Rev.* **2001**, *91*, 909–923. [\[CrossRef\]](#)
33. Yu, C.; Hu, X. Sophistication of China's Manufactured Exports and Determinants. *Transnatl. Corp. Rev.* **2015**, *7*, 169–189. [\[CrossRef\]](#)
34. Asif, M.; Rehman, F.U.; Zheng, L.; Shah, H.S. Does trade with China can make growth in Pakistan more inclusive? pre and post empirical impact of China-Pakistan economic corridor. *Dev. Ctry. Stud.* **2019**, *9*, 57–67.
35. Donaubauer, J.; Meyer, B.; Nunnenkamp, P. Aid, Infrastructure, and FDI: Assessing the Transmission Channel with a New Index of Infrastructure. *World Dev.* **2016**, *78*, 230–245. [\[CrossRef\]](#)
36. Jordan, S.; Philips, A.Q. Cointegration testing and dynamic simulations of autoregressive distributed lag models. *Stata J.* **2018**, *18*, 902–923. [\[CrossRef\]](#)
37. Ianchovichina, E.; Martin, W. Trade Liberalization in China's Accession to WTO. *J. Econ. Integr.* **2001**, *16*, 421–445. [\[CrossRef\]](#)
38. Rehman, F.U.; Noman, A.A. China's outward foreign direct investment and bilateral export sophistication: A cross countries panel data analysis. *China Financ. Rev. Int.* **2021**. [\[CrossRef\]](#)
39. Babatunde, S.A. Government spending on infrastructure and economic growth in Nigeria. *Econ. Res. Ekon. Istraživanja* **2018**, *31*, 997–1014. [\[CrossRef\]](#)
40. Rodrik, D. What's So Special about China's Exports? *China World Econ.* **2006**, *14*, 1–19. [\[CrossRef\]](#)
41. Schott, P.K. The relative sophistication of Chinese exports. *Econ. Policy* **2008**, *23*, 6–49.
42. Gözgör, G.; Can, M. Causal Linkages among the Product Diversification of Exports, Economic Globalization and Economic Growth. *Rev. Dev. Econ.* **2017**, *21*, 888–908. [\[CrossRef\]](#)
43. Mania, E.; Rieber, A. Product export diversification and sustainable economic growth in developing countries. *Struct. Chang. Econ. Dyn.* **2019**, *51*, 138–151. [\[CrossRef\]](#)
44. Osakwe, P.N.; Santos-Paulino, A.U.; Dogan, B. Trade dependence, liberalization, and exports diversification in developing countries. *J. Afr. Trade* **2018**, *5*, 19–34. [\[CrossRef\]](#)
45. Jarreau, J.; Poncet, S. Export sophistication and economic growth: Evidence from China. *J. Dev. Econ.* **2012**, *97*, 281–292. [\[CrossRef\]](#)

46. Kireyev, A. Diversification in the Middle East: From Crude Trends to Refined Policies. *Extr. Ind. Soc.* **2020**. [CrossRef]
47. Hesse, H. Export Diversification and Economic Growth Paper No. 21. In *Commission on Growth and Development*; World Bank: Washington, DC, USA, 2008.
48. Parteka, A. What drives cross-country differences in export variety? A bilateral panel approach. *Econ. Model.* **2020**, *92*, 48–56. [CrossRef] [PubMed]
49. Goya, D. The exchange rate and export variety: A cross-country analysis with long panel estimators. *Int. Rev. Econ. Financ.* **2020**, *70*, 649–665. [CrossRef]
50. Herzer, D.; Nowak-Lehmann, D.F. What does export diversification do for growth? An econometric analysis. *Appl. Econ.* **2006**, *38*, 1825–1838. [CrossRef]
51. Desmarchelier, B.; Regis, P.J.; Salike, N. Product space and the development of nations: A model of product diversification. *J. Econ. Behav. Organ.* **2018**, *145*, 34–51. [CrossRef]
52. Kito, T.; New, S.; Reed-Tsochas, F. Disentangling the complexity of supply relationship formations: Firm product diversification and product ubiquity in the Japanese car industry. *Int. J. Prod. Econ.* **2018**, *206*, 159–168. [CrossRef]
53. Zheng, H.-H.; Wang, Z.-X. Measurement and comparison of export sophistication of the new energy industry in 30 countries during 2000–2015. *Renew. Sustain. Energy Rev.* **2019**, *108*, 140–158. [CrossRef]
54. Li, C.; Lu, J. R&D, financing constraints and export green-sophistication in China. *China Econ. Rev.* **2018**, *47*, 234–244. [CrossRef]
55. Aditya, A.; Acharyya, R. Trade liberalization and export diversification. *Int. Rev. Econ. Financ.* **2015**, *39*, 390–410. [CrossRef]
56. Koopman, R.; Wang, Z.; Wei, S.-J. *How Much of Chinese Exports Is Really Made in China? Assessing Domestic Value-Added When Processing Trade Is Pervasive*; National Bureau of Economic Research: Cambridge, MA, USA, 2008.
57. Guoming, S.B.X. Preference for Sophistication and China's Export Growth—Based on the Extended Gravity Model. *South China J. Econ.* **2012**, *8*. Available online: https://en.cnki.com.cn/Article_en/CJFDTotal-NFJJ201208009.htm (accessed on 6 April 2021).
58. Balamoune-Lutz, M. Trade sophistication in developing countries: Does export destination matter? *J. Policy Modeling* **2019**, *41*, 39–51. [CrossRef]
59. Hu, G.; Can, M.; Paramati, S.R.; Doğan, B.; Fang, J. The effect of import product diversification on carbon emissions: New evidence for sustainable economic policies. *Econ. Anal. Policy* **2020**, *65*, 198–210. [CrossRef]
60. Khan, M.K.; Teng, J.-Z.; Khan, M.I. Effect of energy consumption and economic growth on carbon dioxide emissions in Pakistan with dynamic ARDL simulations approach. *Environ. Sci. Pollut. Res.* **2019**, *26*, 23480–23490. [CrossRef]
61. Khan, M.K.; Teng, J.-Z.; Khan, M.I.; Khan, M.O. Impact of globalization, economic factors and energy consumption on CO₂ emissions in Pakistan. *Sci. Total Environ.* **2019**, *688*, 424–436. [CrossRef]
62. Khan, M.A.; Ahmed, M.; Olah, J.; Popp, J. US Policy Uncertainty and Stock Market Nexus revisited through Dynamic ARDL Simulation and Threshold Modelling. *Mathematics* **2020**, *8*, 2073. [CrossRef]
63. Vernon, R. International Investment and International Trade in the Product Cycle. *Q. J. Econ.* **1966**, *80*, 190–207. [CrossRef]
64. Jozsef, T.; Balogh, J.M.; Torok, A. Networking theory of innovation in practice—The Hungarian case. *Agric. Econ.* **2018**, *64*, 536–545.
65. Xing, Y. China's high-tech exports: The myth and reality. *Asian Econ. Pap.* **2014**, *13*, 109–123. [CrossRef]
66. Xu, B. The sophistication of exports: Is China special? *China Econ. Rev.* **2010**, *21*, 482–493. [CrossRef]
67. Yao, S. Why Are Chinese Exports Not So Special? *China World Econ.* **2009**, *17*, 47–65. [CrossRef]
68. Yang, R.; Yao, Y.; Zhang, Y. Technological structure and its upgrading in China's exports. *China Econ. J.* **2009**, *2*, 55–71. [CrossRef]
69. Rehman, F.U.; Ding, Y. The nexus between outward foreign direct investment and export sophistication: New evidence from China. *Appl. Econ. Lett.* **2020**, *27*, 357–365. [CrossRef]
70. Rehman, F.U.; Khan, D. The Determinants of Food Price Inflation in Pakistan: An Econometric Analysis. *Adv. Econ. Bus.* **2015**, *3*, 571–576. [CrossRef]
71. Sarkodie, S.A.; Strezov, V.; Weldekidan, H.; Asamoah, E.F.; Owusu, P.A.; Doyi, I.N.Y. Environmental sustainability assessment using dynamic Autoregressive-Distributed Lag simulations—Nexus between greenhouse gas emissions, biomass energy, food and economic growth. *Sci. Total Environ.* **2019**, *668*, 318–332. [CrossRef]
72. Pesaran, M.H.; Shin, Y.; Smith, R.J. Bounds testing approaches to the analysis of level relationships. *J. Appl. Econ.* **2001**, *16*, 289–326. [CrossRef]
73. Pesaran, M.H.; Shin, Y.; Smith, R.P. Pooled Mean Group Estimation of Dynamic Heterogeneous Panels. *J. Am. Stat. Assoc.* **1999**, *94*, 621–634. [CrossRef]
74. Khan, M.A.; Khan, M.A.; Abdulahi, M.E.; Liaqat, I.; Shah, S.S.H. Institutional quality and financial development: The United States perspective. *J. Multinatl. Financ. Manag.* **2019**, *49*, 67–80. [CrossRef]
75. Khan, M.A.; Ilyas, R.M.A.; Hashmi, S.H. Cointegration between Institutional Quality and Stock Market Development. *NUML Int. J. Bus. Manag.* **2018**, *13*, 90–103.
76. Haug, A.A. Temporal Aggregation and the Power of Cointegration Tests: A Monte Carlo Study. *Oxf. Bull. Econ. Stat.* **2002**, *64*, 399–412. [CrossRef]
77. Ahmad, M.; Majeed, A.; Khan, M.A.; Sohaib, M.; Shehzad, K. Digital financial inclusion and economic growth: Provincial data analysis of China. *China Econ. J.* **2021**, 1–20. [CrossRef]
78. Virglerova, Z.; Khan, M.A.; Martinkute-Kauliene, R.; Kovács, S. The internationalization of SMEs in Central Europe and its impact on their methods of risk management. *Amfiteatru Econ.* **2020**, 792–807.